TECHNICAL NOTES

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No. 291

GLUING PRACTICE AT AIRCRAFT MANUFACTURING PLANTS AND REPAIR STATIONS

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By T. R. Truax.

This report records observations and recommendations resulting from an inspection trip to representative aircraft manufacturing establishments and repair stations. This inspection was made for the Navy Department and was specifically in reference to gluing practice at the various places visited. The period of the visits was between November 23, 1926 and February 16, 1927.

General Status of Practice

Gluing practice in the aircraft industry does not compare favorably in general with gluing practice in certain other industries. This may be due, in part, to a more or less continuous change and development in aircraft design, to a lack of volume production, and to the large amount of unusual and special forms of material to be glued. In aircraft much of the gluing is done entirely by hand and the quality of work depends in large part upon the personal factor. Machine spreading and pressing equipment, which is used extensively in other industries and which tends to reduce the personal factor, plays a

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minor part in aircraft fabrication. Such equipment as is in use is often unsatisfactory and inadequate.

Preparation of Wood for Gluing

The average moisture content to which wood is reported to be dried and conditioned (about 12 per cent) is generally satisfactory and no serious trouble is expected from this source. There is less assurance, however, that the moisture content of the wood when glued is sufficiently uniform and a more careful check along this line is advisable at some plants. The quality of wood used is for the most part being reasonably well checked, although material showing serious defects, such as excessive cross grain and compression wood, was seen at some plants.

It is recommended that establishments doing repair and overhaul work be provided with suitable equipment for making moisture content determinations and that all wood used be carefully inspected. Trained wood inspectors, competent to pass on the quality of wood used, should be available at major overhaul depots. All wooden parts should be carefully inspected, as at commercial factories making aircraft. Inspection of the material in the rough is not considered adequate.

Inspection of Glue

The casein glue being used was not being inspected in accordance with existing specifications (Navy Spec. 52 G 8, for

example), so far as could be learned at any of the stations or factories visited. There is apparently no check on its water-resistance. Some form of dry block test is usually made but in a number of cases even this test was not in accordance with the specification.

This lack of inspection on water-resistance is regarded as serious, since water-resistance is highly important in a glue under most operating conditions. It should be understood that although a glue is made with a base of casein there is no assurance that it has the required degree of water-resistance. There are a number of casein glues on the market that are almost, if not entirely, lacking in water-resistance, but which show a high dry strength. At the present time the plywood bought from plywood manufacturers is given a severe water-resistance test but no check at all is made on the water-resistance of the casein glue used in the aircraft factories and repair shops.

The difference in water-resistance requirements for grade A plywood (Navy Specificatiom No. 49 P1a) and casein glue (Navy Specification No. 52 G 8) has presented in the past an illogical situation. In the assembly of wings (beams, ribs, etc.), various parts are glued with casein glue to grade A plywood. The casein glue specification has required a wet strength, tested in plywood, of 125 pounds per square inch after soaking for 48 hours while the grade A plywood had to show a strength of 180 pounds per square inch when tested in the same way. In

practice, however, the casein glue has not been checked at all as to water-resistance.

A step has been taken to eliminate this illogical situation in the new plywood specificatiom (No. 49 P1b), just recently issued, in which a single grade with a wet strength requirement of 145 pounds per square inch is made. A similar degree of water-resistance should be required for casein glue and steps should be made to see that this requirement is met im service. Specificatiom No. 52 G 8 and its proposed revisiom will be the subject matter of a separate communication.

Mixing Glue for Use

Much of the glue used is not well mixed. Lumpy, foamy, or too thim mixtures are altogether too prevalent. These results come, for the most part, from poor mixers and improper methods. A standard procedure and definite, complete directions should be prescribed and should be carefully followed by the man doing the mixing. This will reduce the errors due to individual judgment.

It is felt that there is too large a variatiom in the consistency of casein glues used at different plants on the same general type of gluing. This is due chiefly to differences of opiniom of workmen as to the most suitable consistencies for best results. It is, of course, not possible to prescribe a standard proportiom of dry glue and water for different kinds

of glues and all types of gluing. For example, in assembling parts where a small amount of pressure is used the glue must be relatively thin. On the other hand, with heavier pressure the glue should be thicker, especially for gluing ash, hickory, birch, and other hard woods. Greater care should be used to see that the consistency of the mixtures is suitable for the work in hand. This and related problems in gluing will be treated in more detail in proposed publications, entitled "Gluing Aircraft Woods" and a "Manual for Inspectors of Aircraft Wood and Glue for the U. S. Army."*

There are various types of glue mixers in use. Some of the mixers are not well adapted to the work and the equipment will have to be changed before satisfactory results are secured. In most of the plants the stirring, after the dry glue and water are combined, is too rapid, and this results in a foamy mixture, provided the mixing is continued until the glue is well dissolved. In other cases lumps are allowed to form and remain in the mixture or an excessive amount of air is whipped into the glue in an attempt to beat out the lumps. To overcome these troubles two-speed mixers are needed, one having speed that will give rapid agitation while the dry glue is being added to the water and the other for slow stirring during the completion of the mixing. The dough type mixer, shown in Figure 1, has proven to be well adapted for casein glues and is recommended where new

*This has been printed and is available for purchase from the Superintendent of Documents, Government Printing Office, Washington, D. C., at 75 cents per copy, for non-governmental agencies.

machines are installed. It can be procured in different sizes. The particular machine shown is equipped with an electric motor and two sizes of mixing bowls in which batches of from 2 to 20 pounds of wet glue can be mixed satisfactorily.

Spreading the Glue and Pressing the Joints

Present methods of spreading the glue and of applying pressure are not favorable for producing joints of maximum strength and uniformity, but ways and means of improvement are less obvious than in most of the other unsatisfactory conditions encountered. The many small or odd-shaped pieces and the small total quantity of material used make the application of improved ways and means, now employed in other industries, somewhat difficult in aircraft manufacture. It is believed, however, that distinct improvement is possible in many cases.

Glue is spread almost entirely by hand. Mechanical means give a more uniform and reliable spread and reduce the personal factor and their more extensive use in aircraft is highly desirable. The essential in spreading glue is to apply the proper amount uniformly over the surfaces to be joined. At present an excessive amount is being spread on many of the surfaces while on others the spread is insufficient and uneven. Too small a spread is more harmful than too much, but either is to be avoided.*

*This point is covered in more detail in the proposed publication on "Gluing Aircraft Woods."

It requires care to get an even application, either by hand or machine but hand application is susceptible to more variation.

In some factories small rolls are being used advantageously to coat such parts as cap strips. A further development and application of this form of spreader is highly desirable and its more extensive use is, therefore, recommended. Development along this lime is needed and it is possible that glue machinery manufacturers can give assistance if the problem is presented to them.

Gluing investigations have shown that the most reliable glue joints are made under comparatively high pressures, such as 100 to 200 pounds per square inch. High pressures are especially important with thick glues, such as casein glues. In practice, however, the variation in pressure is enormous - ranging from a few pounds to 400 or 500 pounds per square inch and furthermore, in many cases, the pressure is not uniform over the joint. There is no attempt generally to use the same amount of pressure under otherwise similar gluing conditions. Much can be done in checking up the pressures used and adjusting them within the recommended range. This applies generally but particularly to curved laminated members where the pressure used is often insufficient.

In much of aircraft gluing the only pressure applied is by the insertion of nails or screws. This is not likely to give uniform pressure over the joint, especially where the pieces

are thin. In such cases it is recommended that pressure be applied by means of clamps or jack screws, wherever possible.

The pressure may be applied either before or after the insertion of the metal fasteners. If afterwards, the time elapsing between spreading the glue and pressing should not exceed 20 minutes. If pressed first it is best to allow the glue to set for at least five or six hours before inserting the nails, but the joint need not be under pressure all this time.

It is recommended that the pressure be applied for at least one-half hour but where such is not feasible a momentary application of the load after inserting the nails or wood screws will be better than no pressure at all. This refers especially to gluing box beams and other parts in wing construction. Under present practice there is considerable variation in the use of pressure on such members. In some cases very small "C" clamps, carpenters' wood clamps and large screw clamps are used in joints which in other plants are nailed only. This indicates the practicability of a more general use of clamps, pressure screws, etc.

The lapse of time between spreading the glue on the wood and pressing, is in some cases excessive. If this period exceeds 20 minutes, the results are generally questionable. Where light pressures are used or nailing only is resorted to the lapse of time between spreading and pressing must be carefully controlled.

Gluing Different Woods

In general, there is not enough care used in gluing hard woods, such as ash and birch. The principal requirements in gluing these woods are: a thick glue mixture, a high pressure (150 to 200 pounds per square inch) and a relatively short lapse of time between spreading the glue and pressing. On the other hand, Sitka spruce is easy to glue and satisfactory joints can be made under a wider range of gluing conditions.

Miscellaneous Problems

In some instances end grain surfaces are glued - such as scarf joints or blocks - at fitting points in box beams. The methods ordinarily used on side grain surfaces are not very satisfactory and special precautionary measures should be used in such cases. The following procedure is recommended:

Size the end-grain surfaces with a glue mixture somewhat thinner than that used for regular gluing. A sizing mixture of 1 part glue to 3 parts water is recommended for animal and prepared casein glues which meet aircraft requirements. The sizing coat should be allowed to dry on the wood surfaces. The mixture for the final gluing should be thicker than for lateral surface gluing - about 1 part glue to 1.8 and 2 parts water for caseim and animal glues, respectively. Both surfaces of the joint should be coated with glue and approximately 200 pounds

pressure per square inch applied. In the case of animal glue care should be used that other conditions are maintained which will cause the glue to come to the proper consistency for pressing.

The glue squeezed out at the joint is frequently not removed. Instances were seen where the finish over the glue had checked more than over the wood. It is suggested that the glue squeeze-out be removed. This can be done conveniently with a square and spatula or similar tool or with a cloth, while the glue is still soft.

Recommendations

The more important recommendations may be summarized as follows:

1. All glues should be tested in strict accordance with government specifications. It is particularly important that all casein glues used be tested for water-resistance and there should be positive assurance that this is done.

2. Improve and standardize the methods of mixing casein glue. The glue should be well dissolved and comparatively free of lumps and foam. A two-speed mixer should be provided.

3. Improvements should be worked out in applying the glue so as to reduce the personal factor. Small glue rollers and similar mechanical devices will be useful in this respect.

4. A more extensive use should be made of pressure in gluing. This applies particularly to the pressing of joints before the insertion of nails or screws. The amount of pressure now applied should be checked and made to conform to best practice.

5. Greater care is needed in gluing ash and other hard woods.

6. The strength of end-grain joints can be improved in most cases by a special procedure, including a sizing treatment.

7. Excess glue squeezed out at the joints should be removed.

Forest Products Laboratory,
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FIGURE NO. 1